Optical Bench for LISA-like missions

Completed Technology Project (2014 - 2017)

Project Introduction

The detection of B-modes in the microwave background has rattled the scientific community and further enhanced the large scientific interest in gravitational waves and gravitational wave astronomy. The first direct detection of gravitational waves by Advanced LIGO and maybe also by pulsar timing arrays in the second half of this decade will be another watershed event which will start a new era in astronomy and astrophysics. However, the holy grail of gravitational wave astronomy will be opened by a LISA-like mission. Only space provides the environment that allows to cover the signal-rich mHz frequency range where we expect to see gravitational waves from massive black hole mergers, compact galactic binaries, and many other sources. All mature concepts use laser interferometry between free falling test masses separated by millions of km. The central piece in all these concepts is a stable optical bench which is used to prepare and exchange the laser beams between the different arms. It has always been assumed that the base material for the optical bench has to be one of the ultra-low expansion glasses such as Zerodur or ULE to meet the pm/'Hz stability requirements. This very conservative approach was a reflection of the state-of-the-art in frequency stabilization experiments which used optical reference cavities in the early '90s. It is not surprising that the LISA pathfinder (LPF) uses also an all Zerodur bench where each optical component is precision bonded to the bench using hydroxide bonding, a non-reversible bonding technique. The manufacturing of this bench was a very time consuming one-mirror-a-day effort and was one of the highest risk items in terms of schedule and cost. The original LISA design uses the same approach except that the LISA bench is far more complex than the LPF bench and manufacturing of the required 10+ benches, six flight units and at least four pre-flight models and spares, will be even more time consuming and expensive. We question the need for ultra-low expansion glass for the optical bench. We will streamline the design of the bench and explore other materials and assembly techniques to significantly simplify the manufacturing process. Why are we confident that this is possible? One argument is that in early LISA designs the reference cavity was also part of the bench. This cavity drove the requirements to 30 fm/'Hz, a factor 30 more stringent compared to the current requirements. Since the cavity has now been removed from the bench, the requirements have been relaxed. A second argument is that we demonstrated pm/'Hz performance for a number of different materials and structures which are all candidate materials for the telescopes which also have to meet the same requirements over actually a larger distance. Our objective is to take a fresh look at the optical bench. We will redesign core parts of the interferometer bench with a focus on reducing the number and lengths of critical paths and moving non-critical parts away from the core part of the bench and sometimes even into optical fibers. We also propose to use different materials and assembly techniques for the optical bench and strongly believe that they will still meet the pm/'Hz requirement and will also be stable on long time scales. This confidence is based on nearly ten years of experience during which we investigated different materials and structures for the telescopes

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Astrophysics Research and Analysis

Project Management

Program Director:

Michael A Garcia

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which we plan to apply now to the optical bench.

Primary U.S. Work Locations and Key Partners

Organizations Performing Work	Role	Type	Location
Division of Sponsored Research - University of Florida	Supporting Organization	Academia	St Augustine, Florida

Primary U.S. Work Locations	
Florida	Maryland

Project Management *(cont.)*

Program Manager:

Dominic J Benford

Principal Investigator:

Guido Mueller

Co-Investigators:

John W Conklin
Jeffrey C Livas
Brian Prindle
James I Thorpe
Giacomo Ciani

Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  - TX12.2 Structures
    - TX12.2.1 Lightweight Concepts

Target Destination

Outside the Solar System